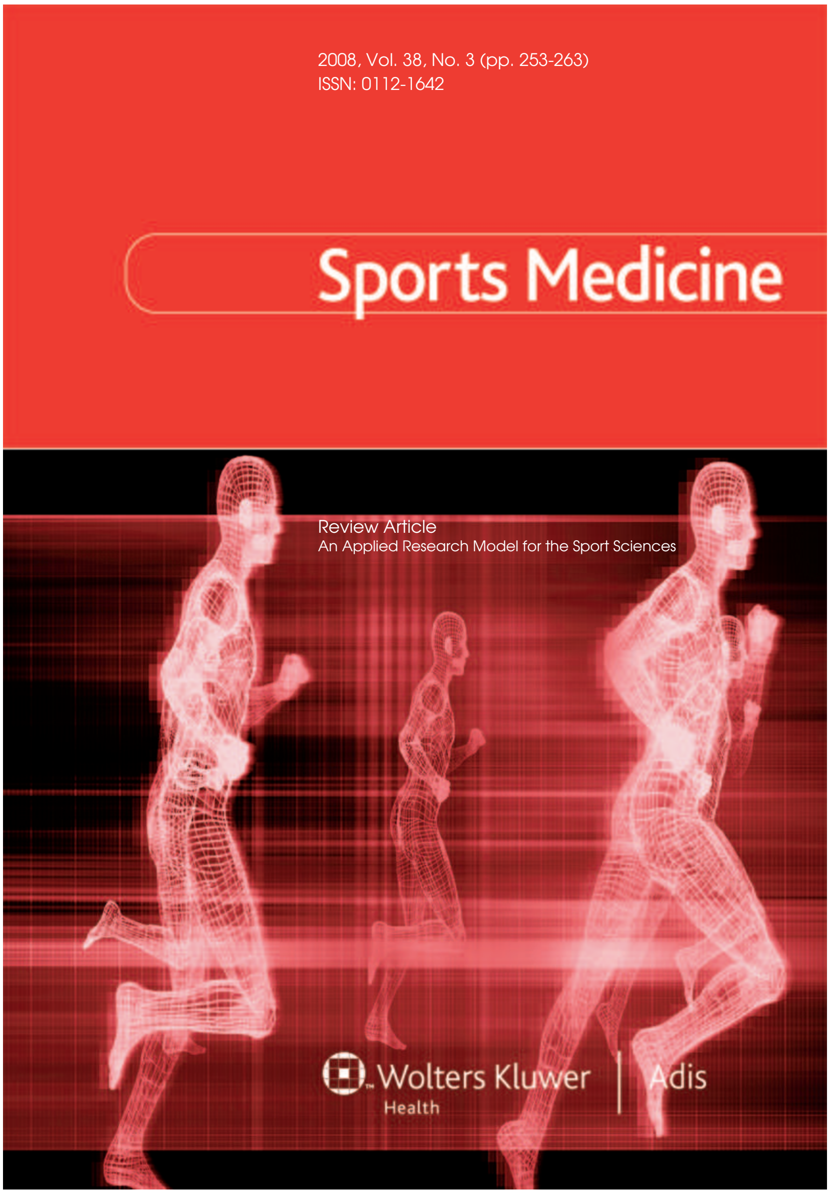
2008, Vol. 38, No. 3 (pp. 253-263)
ISSN: 0112-1642
Sports Medicine
Review Article
An Applied Research Model for the Sport Sciences
Wolters Kluwer Health
Adis

REVIEW ARTICLE

Sports Med 2008; 38 (3): 253-263
0112-1642/08/0003-0253/$48.00/0

An Applied Research Model for the Sport Sciences

David Bishop

Faculty of Motor Science, University of Verona, Verona, Italy

Contents

Abstract 253
1. Introduction 254
   1.1 What is Sport Science? 254
   1.2 Does Sport Science Influence Practice? 254
   1.3 Structure of Scientific Inquiry 254
2. An Applied Research Model for the Sport Sciences 254
3. Stage 1: Defining the Problem 255
4. Stage 2: Descriptive Research 256
5. Stage 3: Predictors of Performance (Regression Studies) 257
6. Stage 4: Experimental Testing of Predictors 257
7. Stage 5: Determinants of Key Performance Predictors 258
8. Stage 6: Intervention Studies (Efficacy Trials) 258
9. Stage 7: Barriers to Uptake 259
10. Stage 8: Implementation in Sporting Setting (Effectiveness Trials) 260
11. Conclusions 261
    11.1 Where to from Here? 262

Abstract

Sport science can be thought of as a scientific process used to guide the practice of sport with the ultimate aim of improving sporting performance. However, despite this goal, the general consensus is that the translation of sport-science research to practice is poor. Furthermore, researchers have been criticised for failing to study problems relevant to practitioners and for disseminating findings that are difficult to implement within a practical setting. This paper proposes that the situation may be improved by the adoption of a model that guides the direction of research required to build our evidence base about how to improve performance.

Central to the Applied Research Model for the Sport Sciences (ARMSS) described in this report is the idea that only research leading to practices that can and will be adopted can improve sporting performance. The eight stages of the proposed model are (i) defining the problem; (ii) descriptive research; (iii) predictors of performance; (iv) experimental testing of predictors; (v) determinants of key performance predictors; (vi) efficacy studies; (vii) examination of barriers to uptake; and (viii) implementation studies in a real sporting setting. It is suggested that, from the very inception, researchers need to consider how their research findings might ultimately be adapted to the intended population, in the actual sporting setting, delivered by persons with diverse training and skills, and using the available resources. It is further argued in the model that a greater understanding of the literature and more mechanistic studies are essential to inform subsequent research conducted in real sporting settings.

The proposed ARMSS model therefore calls for a fundamental change in the way in which many sport scientists think about the research process. While there is no guarantee that application of this proposed research model will improve actual sports performance, anecdotal evidence suggests that sport-science research is not currently informing sport-science practice as we would hope and that sport-science researchers need to consider a new approach.

1. Introduction

1.1 What is Sport Science?

Sport science is a multi-disciplinary field concerned with the understanding and enhancement of human sporting performance. Sport science can be thought of as a scientific process used to guide the practice of sport with the ultimate aim of improving sporting performance.[1] It is about using the best available evidence at the right time, in the right environment, for the right individual to improve their performance. In order to achieve at least some of these goals, it is necessary to use the findings of well designed research studies and to translate them into everyday practice.[2]

1.2 Does Sport Science Influence Practice?

While the efficacy of translating sport-science research to practice has not been investigated, research from other disciplines indicates that there is a widening gap between scientific knowledge and practice[3] and that, in general, the utilization of research in practice is poor.[4] For example, it has been estimated that it may take as long as 1 or 2 decades for original medical research to be translated into routine medical practice.[5] Numerous complex and still poorly understood factors, beyond the scope of this article, contribute to the lack of transfer from research to practice (e.g. conservative coaching practices, outdated coach education and publication of scientific findings in highly specialised scientific journals, etc.). However, the structure of scientific inquiry itself (i.e. the way in which research is conducted) undoubtedly plays a role in the extent to which scientific innovations are implemented in everyday practice.[6]

1.3 Structure of Scientific Inquiry

In the field of nursing, researchers have been criticized for failing to study problems relevant to practitioners and for disseminating findings that were largely incomprehensible to a majority of nurses.[7] As a result, many nurses do not perceive research findings as relevant to their practice.[7,8] Although a similar study has not been conducted for the sport sciences (and is needed), it is likely that similar views are held by many sport-science practitioners.[1] In a related field, coaching science has also been criticised for conducting research that does not impact on coaching practice.[9] This situation may be improved by the development of a model that guides the direction of research required to build our evidence base about how to improve performance. Researchers in other fields have also argued the need for a logical progression of research through which promising intervention ideas should proceed.[10,11]

2. An Applied Research Model for the Sport Sciences

The Applied Research Model for the Sport Sciences (ARMSS), described in this report, provides a framework by which research efforts may be better integrated and directed towards improving sporting performance (figure 1). It is suggested that researchers should refer to this model in the initial design or

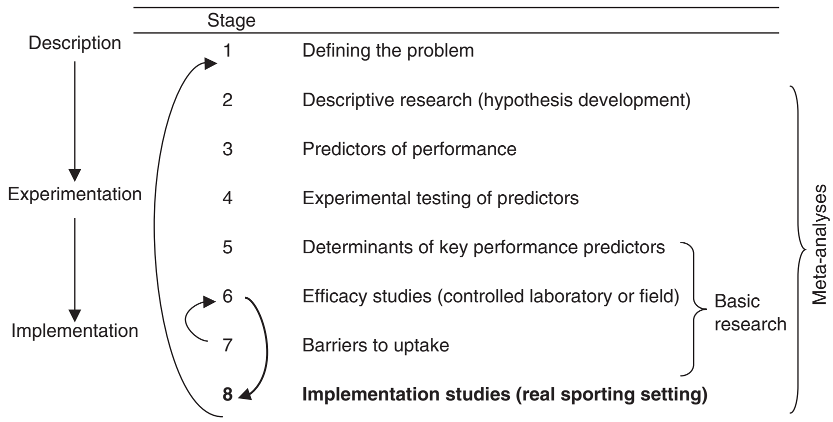

Fig. 1. An applied research model for the sport sciences. Although depicted as a series of steps, in order for the model to be most effective, it should be seen as a research loop that is iterative and bidirectional and allows for unexpected findings and new research directions to emerge.

concept stage of their research, in the analysis, interpretation and report preparation stages, and again when follow-up experiments are devised. Although the model is presented as a linear, multiphase model, it is important for researchers and practitioners to keep in perspective that research is complex. The translation of research to practice rarely progresses neatly from one well defined stage to the next, and realistic models acknowledge the iterative, bidirectional nature of scientific discovery.[6,12] Any of the proposed phases of research could and should inform any other phase; sometimes, stages may be performed concurrently in one study. The model should also be flexible enough for serendipitous, but potentially important, findings to redirect the line of research when required.

The current proposed model is based on previously described models for both injury prevention[13,14] and health research.[5] An important feature of the proposed model is the need for researchers to consider issues that affect the implementation of research ideas from the very inception of the programme. This is more easily said than done, as the career progression of academic researchers often depends more on the number and quality of their publications, and not on the implementation of their research findings. However, to improve sporting performance, the findings from research need to be accepted, adopted and complied with by the athletes, coaches and sport-science staff at whom they are targeted. As such, negotiations and collaborations between academically trained researchers and practitioners who have experience with field work are critical. Only research leading to practices that can and will be adopted can improve sporting performance.

Some may question the number of phases proposed (more or less fine distinctions could be made). However, the key point is that sport-science research needs to move away from a tradition that has focused on outcomes that do not explicitly consider how that research will ultimately be applied. From the very inception, researchers need to consider how the research findings might ultimately be adapted to the intended population in the actual sporting setting, delivered by persons with diverse training and skills and using the available resources.[12]

3. Stage 1: Defining the Problem

It may seem like stating the very obvious to say that the research process should begin with a definition of the problem. However, while most researchers intuitively understand this requirement, it is not always adhered to. Within the scientific literature, there appear to be many articles that have arisen from convenient access to a data set, and the possibility of a publication, rather than being driven by a problem to be solved (i.e. hypothesis-driven studies). The first step of this model is for sport-science researchers to identify the types of real-world problems and issues that coaches and athletes face. In this respect, athletes, coaches and sport-science staff should help to illuminate and prioritise broad research questions that need to be answered. It is important to keep in mind, however, that athletes and coaches do not always appreciate what they are doing and what types of changes are most likely to result in performance improvements. Therefore, athletes and coaches may not always be in the best position to suggest solutions to the broad research questions proposed.

It is at this stage that researchers need to ensure that they have an excellent understanding of the underlying science that relates to the identified research problem. Reviews or meta-analyses should also be undertaken to determine the state of the knowledge for the particular problem identified by the researcher and sport-science practitioners. Without this solid understanding, experiments are likely to be poorly conceived and unlikely to address questions that will contribute to performance. During this stage, it is also important to learn about the sport and to talk to athletes, coaches and officials about issues related to individual and team performances. Researchers should not proceed to the next stage of the model until they have clearly defined the problem at hand and have a thorough understanding of the literature.

4. Stage 2: Descriptive Research

It could be argued that far too much sport-science research is descriptive and that we need to move away from too many studies that simply describe what is occurring.[15,16] Once again, this probably reflects the relative ease of publication and ready access to data. Nonetheless, once a problem has been identified (stage 1), high-quality descriptive research is crucial for underpinning all other stages of the ARMSS. Research at this stage may also include profiling studies that describe what is currently occurring in a particular field (e.g. nutritional habits, motion analyses, physiological and psychological characteristics, training practices and other observations regarding successful performance). An example of descriptive research is that by Atkinson et al.,[17] who reported that cyclists perform better in evening than in morning races. Descriptive research may also include cross-sectional studies; for example, what are the differences between elite and non-elite athletes of the same sport, or between athletes of different sports? Research at this stage should be conducted because it moves the research question forward.

Instead of re-inventing the wheel, it is important to ensure greater access to the wealth of descriptive data that is already out there, tucked away in the labs of various sporting institutes and clubs, in the minds of athletes, coaches and sport-science staff, and in the libraries of universities and institutes. While there is probably little time and motivation to publish such data (and most journal publishers are reluctant to do so because of an emphasis on original research), such observations may provide unique and valuable insights to inform the stages that follow. At the same time, observations are likely to be more valuable if they are carefully made. Therefore, the training of both coaches and sport-science practitioners should include instruction in basic research methodology.

Stage 2 of ARMSS may also include methodological studies, as descriptive research will only contribute if sufficiently valid and reliable methodologies are developed to collect data. However, it is important to avoid too many methodological studies that are only slight variations on the valid and reliable tests that we currently have available. There is also a need to standardize both the terminology and test protocols used in sport-science research. At all levels (from coaches through to researchers), more training in statistical methods is required to ensure that valid collection and interpretation of the descriptive data is performed.

5. Stage 3: Predictors of Performance (Regression Studies)

Once descriptive studies (stage 2) have been performed, which provide coaches and sport scientists with an indication of where to look for solutions, stage 3 then involves research to better understand factors that are likely to affect performance. Typically, this would be accomplished by investigating relationships between predictor variables and actual sports performance (for example, research investigating determinants of repeated-sprint ability[18] or endurance performance[19]). Subsequent experimental studies cannot be performed until this information is available because the specific factors to be modified, and how best to modify them, are not yet clear. Importantly, such studies cannot elucidate direct mechanisms, but can only yield important indications of those factors that could potentially be modified to improve actual sports performance. Spurious associations may be identified as a result of chance, bias or failure to control for confounding variables.

The greater the association between each variable and actual sports performance, the higher the likelihood that any observed relationship is causal. Care must be taken, however, to examine confidence intervals and sample sizes. If there is a true causal relationship, one would also expect to see the association replicated in other studies and other subgroups of the population. Unfortunately, because of the emphasis on 'novel findings' by journals, this crucial step of replication of the original results rarely occurs. While accepting the need to encourage novel research, researchers should also attempt to replicate previous findings within their novel studies (e.g. investigate and report previously identified correlations alongside the novel aspects of their studies). Identified relationships are also more likely to be causal if they are consistent with existing knowledge and other data in the field. However, even if all the above holds true, researchers, in collaboration with coaches and athletes, must consider alternative explanations for the observed relationships. These last two points require an excellent basic theoretical and practical knowledge of the area and of the factors that could potentially influence sports performance. However, it is important to remember that even when all the above factors are considered and weighed up against each other, regression studies only provide evidence for causal relationships. Experimental testing of these relationships needs to be performed in the following stages.

6. Stage 4: Experimental Testing of Predictors

Stage 4 of the ARMSS involves strengthening the case that the previously identified associations (stage 3) are likely to be causally related to sports performance. Once an association has been demonstrated (stage 3), such studies are important to demonstrate whether the observed association is likely to be causal. Typically, these studies involve the manipulation of one variable (while attempting to control or match for other variables) and measuring the subsequent effect on performance. Randomized, double-blind studies (with a placebo or control condition) are one appropriate research design for this purpose. For example, having identified an association between blood buffer capacity and repeated-sprint performance,[20] researchers provided support that this might be a causal relationship by acutely increasing blood buffer capacity (via sodium bicarbonate ingestion) and demonstrating a significant improvement in performance.[21] Other examples may include computer modelling studies or 'knock-out' mice studies (to determine whether removal of a physiological process affects some aspect of performance). Stage 4 of the ARMSS may also include studies where subjects are matched on one variable, but not another. For example, to determine whether associations between the lactate threshold and endurance performance[22] were causal or explained by other factors such as a high maximal oxygen uptake ($\dot{V}O_{2max}$), Coyle et al.[23] matched subjects for $\dot{V}O_{2max}$ but not the lactate threshold. The greater endurance performance in subjects with a higher lactate threshold, but similar $\dot{V}O_{2max}$, provided support for previous observations (regression studies) suggesting that the lactate threshold was an important determinant of endurance performance. However, results of these studies must be interpreted with caution, as it is very difficult to control all the variables that may confound previously observed relationships. Furthermore, the results may be population specific.

7. Stage 5: Determinants of Key Performance Predictors

Stage 5 of the ARMSS seeks to determine the best intervention(s) to alter the chosen predictor(s) of sports performance (e.g. using the examples in stage 4, what is the best type of training to improve buffer capacity or the lactate threshold?). This needs to be strongly guided by the previous two stages where factors likely to affect performance have been identified and experimentally tested. If not, researchers may find themselves doing a great deal of research (probably very interesting) establishing the best method to alter a factor that does not in fact influence sports performance. In many cases, a line of research may begin here if other researchers have already established those factors likely to affect performance. This stage may include many controlled studies to determine the best intervention (frequency, time, type, etc.) to alter the chosen predictor of performance. For example, research by Edge et al.[24,25] has demonstrated that high-intensity training is required to improve buffer capacity, but that training above the intensity associated with $\dot{V}O_{2max}$ does not appear to result in greater improvements. The word ‘intervention’ here is used in its broadest sense and may refer to training, nutritional guidelines, technique alteration, feedback methods, etc. Research that seeks to determine the causal mechanisms responsible for changes in the chosen predictor variables may also form part of this stage. Once the best intervention(s) to improve the chosen predictors have been identified (often based on the results of many studies performed by different research groups), efficacy studies (stage 6) can then be performed to determine if altering the predictor variable also affects performance.

8. Stage 6: Intervention Studies (Efficacy Trials)

Efficacy trials can be defined as a test of whether an intervention has a substantial positive or negative effect on actual sports performance when delivered under optimum/ideal conditions.[10] For example, Edge et al.[26] used the intervention that best improved buffer capacity to demonstrate that this also improved repeated-sprint ability. Efficacy trials are characterized by strong control in that a standardized intervention is delivered in a uniform and tightly controlled fashion to a specific, often narrowly defined, homogenous, motivated population. This approach should include random selection of participants, random assignment to conditions, and possible use of placebos (ideally double-blind) or cross-over designs. Highly-controlled studies conducted in field settings are also included in this stage, as they are conducted within an ‘artificial environment’ that include resources (and restrictions) often not available to coaches and athletes. Because of the standardization and strict control of efficacy trials, any substantial positive (or negative) effect can be more strongly attributed to the intervention being studied. Such a reductionist approach (i.e. understanding effects by isolating them and removing them or controlling other factors) has contributed much to the advancement of science and theory.[27]

Studies from ARMSS stage 6 are likely to generate exciting research findings that will be published in high-impact journals. However, such research is often criticized as not being transferable to the field or the ‘real world’. The need for tight control might also lead to interventions that have a lower probability for success in ‘real world’ settings, such as the competition arena or training field. Nonetheless, if an intervention is not efficacious under tightly controlled conditions, it is very unlikely to have an impact in the less controlled ‘real world’. This stage is therefore essential to inform potential interventions in the field. Further research (stage 8) is required to determine if the intervention effect is large enough to make a difference in the applied setting – or if it interacts positively or negatively with other training factors.

To further enhance the transferability of the research findings derived from this stage, researchers need to be more transparent when describing their studies and associated findings (see the CONSORT model, figure 2).[28] How were subjects recruited? Was there a recruitment bias towards highly motivated individuals or some other type of individual? Who was excluded and what was the participation rate of those eligible? How was the randomization or distribution of subjects performed? What was the compliance with the intervention? What were the subjective perceptions of the participants to the intervention (good and bad)? What were the withdrawal rates and why did participants not complete the intervention? Were there any adverse effects attributed to the intervention (physical or psychological)? What were the characteristics of those delivering the intervention (e.g. supervising the training)? What were the time and financial costs required to deliver the intervention? Researchers often know the answers to these questions, as they discovered such information while executing their research. However, even the most applied journals omit this type of useful, practical information. Greater transparency regarding issues that might affect implementation will aid in the subsequent identification of barriers to uptake for the proposed intervention (stage 7) and assist the design of implementation studies to be performed in a sporting setting (stage 8).

9. Stage 7: Barriers to Uptake

While there are exceptions, sport-science researchers often do not understand and appreciate the

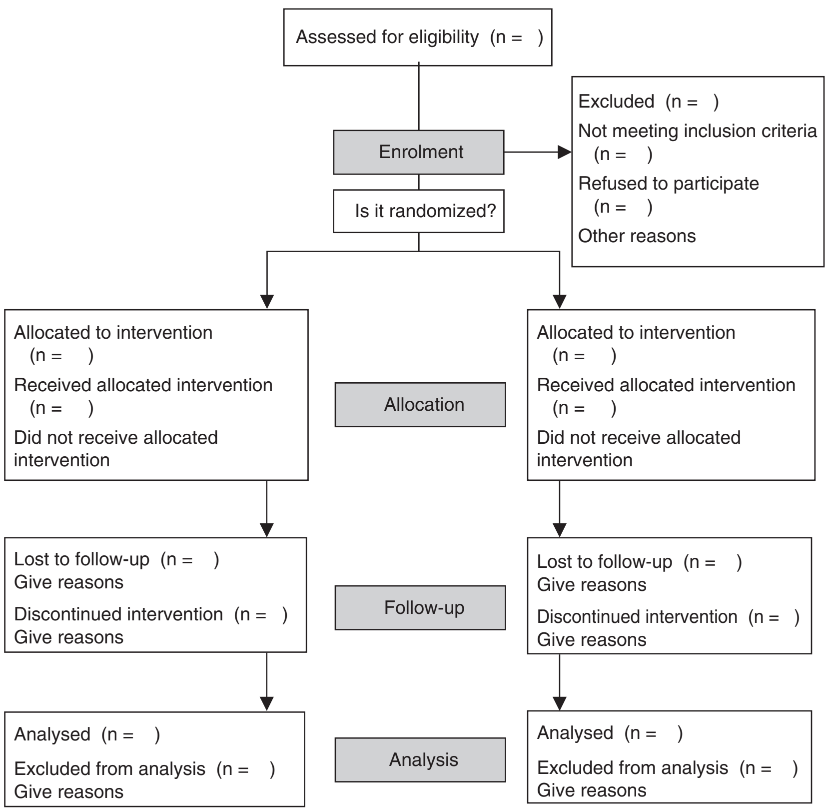

Fig. 2. The Consort E-flowchart.[29]

many issues that constrain the work of coaches and their sport-science staff.[30] Coaches have to contend with injuries, motivational considerations, concurrent training, the need for recovery, illnesses, competition schedules, insufficient time, and lack of equipment or expertise to carry out the programme as tested in the controlled, experimental situation. The ARMSS stage 7 is therefore concerned with barriers (and motivators) to uptake of the new idea. For any implementation to occur, an appreciation of the infrastructure available to the coach and athlete is also required. What are the manpower, finance, equipment, time and other resources required to implement the proposed intervention? Before moving on to ARMSS stage 8 (implementation and evaluation in the sporting setting), or back to one of the earlier stages, it is crucial to analyse the factors that may affect the implementation of ideas in the field. This process may also include information about coach preferences and how the new intervention can be 'marketed' to coaches, athletes and sport-science staff with the additional benefit of maximizing receptivity of the new idea.[31]

To my knowledge, this type of research has not been published in the sport-science literature (and would be useful). Such studies will require an understanding of qualitative research approaches (e.g. interview techniques ranging from free to structured) and should examine and evaluate the conditions that impede or facilitate widespread use of the research. While such factors should be considered from the very beginning of the research, many factors that may moderate the effectiveness of an intervention often cannot be anticipated until a practice has been exposed to a broader range of contexts and subject characteristics.[32] As a result of such analyses, the recommendation may be that additional, perhaps even more basic, research might lead to refinements that can improve the ultimate practical application of the research findings. Thus, issues of external validity (i.e. moderator variables) should not only be left until later effectiveness trials (stage 8), but may need to also be addressed in additional efficacy studies (i.e. return to stage 6). For example, further efficacy studies of an intervention could be conducted in the target population under the time and equipment constraints of the real sporting setting.

10. Stage 8: Implementation in Sporting Setting (Effectiveness Trials)

For the transfer and adoption of the research outcomes from research to be effective, evidence must show that the use of the innovation is feasible and effective in practice (and more effective than current practice).[33] The ARMSS stage 8 therefore involves implementation and evaluation of an intervention when delivered in the real sporting setting. That is, how effective is the scientifically proven intervention (developed from the previous stages) when applied to the target population, and within the constraints of limited time and resources, possible different expertise levels of the coaching staff, and the other activities performed by athletes. Methodological designs may be more variable, and implementation may contain greater error variance or sources of bias, than under controlled conditions. However, the results obtained are likely to be more relevant and more likely to be adopted by sport-science practitioners. With effectiveness trials, sport scientists seeks to embrace and study the complexity of the sporting world, rather than attempting to ignore or reduce it by studying only isolated situations. Negotiations and collaborations between academically trained researchers and practitioners who have experience with field work are essential for real-world effectiveness trials to be conducted optimally.[12,31] Such collaboration may run contrary to a traditional setting of scientists who tend to work in their own domains and not communicate well with practitioners in other domains.[34] Caution must be exercised when interpreting the results of effectiveness trials, as some factors that have genuine relevance for performance may not be recognized because of improper implementation, confounding variables or weak acceptance or adherence by participants.[10,11] Thus, it is essential to maintain scientific rigour when conducting effectiveness trials in the sporting setting.

An example of this type of research from the injury-prevention literature is the work of Elliott and Khangure.[35] Previous research had identified that cricket fast bowlers had an increased incidence of lumbar disk generation (the problem) and that this was related to technique (regression studies). Previous studies had also identified educational approaches that could be used to alter technique (efficacy trials). Elliott and Khangure[35] then implemented a 3-year educational intervention with a fast-bowling development squad and demonstrated that such an intervention was effective in altering technique and reducing the incidence and progression of lumbar spine disk degeneration in a real-world, sporting setting. Unfortunately, there are currently very few studies of this type in the sport-science literature.[36] To truly make an impact on performance, we need more experiments that test the effectiveness of interventions in typical (‘real world’) settings.

As the ultimate goal of the research, this could be considered the final stage of the research loop. Once again, however, when the previous steps have already been performed by others, researchers may consider starting their research here. However, researchers should not start here, evaluating the effectiveness of some current practice, if the previous stages have not been performed and performed well. A good example of why not is the time and resources wasted testing the effectiveness of nasal strips (remember them?), without any evidence that the delivery of air through the nose actually limited sports performance? The same could be said for most of the recovery literature that tests the effectiveness of current recovery practices, with little understanding of the underlying factors that contribute to post-exercise soreness and how best to ameliorate these factors. This trend for sport-science research to desire quick translation, to implement available knowledge into practice immediately, is laudable in terms of trying to optimize the information and training provided to athletes. If the research base is inadequate, application may need to wait. While it may be a mistake to begin the research loop here (without a proper understanding of the determinants of performance and the efficacy of interventions designed to alter these determinants), researchers should at least think about this desired endpoint from the very beginning.

11. Conclusions

To date, little research has sought specifically to examine the implementation of available sport-science research or to develop research models that have the potential to lead to improvements in the way sport-science research is conducted. More research in this area is required to improve the acceptance of sport science by coaches and athletes. The current model proposes that the relevance of the subject population and study setting should be considered regardless of the study design (and stage of the model). It further suggests that the Impact of research should be considered as the product of Efficacy (E) and Implementation (I) (Impact = $E \times I$). It is not enough to produce a highly efficacious intervention. To affect sport performance, an intervention must also be implemented.

There is no doubt that some will criticize this model as taking too long and not delivering results quickly enough. However, why should sport-science researchers worry about wasting years when they could be wasting decades? Without a solid mechanistic base, much of sport-science research is likely to be ‘hit and miss’ and, more importantly, is unlikely to achieve its ultimate goal, which is to improve performance. Key gaps in the evidence informing practice will only be recognized when the sport-science community frequently consults the evidence base for answers and makes efforts toward targeting future research to informing those gaps identified in an accepted, applied research model. As called for by Haag,[37] an “integration paradigm” is required whereby research guides practice, but practice also guides research. It is important to note that all researchers do not necessarily need to perform all stages of the model. However, each stage of research needs to be informed by the other stages, and there needs to be greater communication between those who perform each stage and between those who will ultimately implement the research.

11.1 Where to from Here?

The proposed ARMSS model calls for a fundamental change in the way in which many sport scientists think about the research process. It will be difficult for some sport scientists to quickly discontinue practices in which they have been trained and become comfortable, practices that have produced pleasing careers and expanding publication records. It is important, however, that some type of research model is introduced into both sport-scientist and coach training programmes. These approaches should be discussed in undergraduate and graduate sport-science courses. There will no doubt be arguments about the specific components of the research model proposed here. However, it is difficult to argue against the importance of a model that guides the research process with an understanding and appreciation of the eventual implementation settings. The requirement of a ‘practical applications’ section in some sport-science journals, such as the *Journal of Science and Medicine in Sport*, should be adopted by more journals to encourage researchers to consider how their findings will be implemented. During their studies, sport scientists should also be given scholarship opportunities to work closely within elite sporting structures to gain a better understanding of the questions that need to be answered and the constraints of working within a real-world, applied sporting setting. Sport scientists also need to convince funding agencies to support all stages of the model, not just the tightly controlled experimental stages.

It is important to note that the proposed ARMSS model is only concerned with delivering more relevant information to practitioners. It is beyond the scope of this article to discuss the complex issue of how to better ensure implementation in practice. Further discussion is warranted on the equally important issues of how to better ensure that appropriate innovations are brought to the attention of practitioners and ensuring that practitioners have the skills and resources to implement such innovations. Translational research is an important area and deserves greater attention in the sport sciences. Funding support for translational research, which is collaboratively undertaken by researchers and sport-science practitioners, is also needed.

There is no guarantee that application of this proposed research model will improve actual sports performance. Some may argue that translation occurs naturally without the need for extensive formalization of the research process. Involvement of multiple stakeholders from the beginning might not always yield the best scientific returns. It is also possible that adherence to the proposed model might result in some wasteful collaborations and that it is more efficient for scientists to remain in the lab and practitioners to remain in the sporting arena. Anecdotal evidence, however, suggests that research is not currently informing sport-science practice as we would hope and that a new approach is warranted.

Acknowledgements

This paper is based on an invited lecture given at the 2nd Australian Association for Exercise and Sport Science (AAESS) conference: From Research to Practice. The author would also like to acknowledge the many sport scientists who read drafts of this document and provided valuable feedback. No sources of funding were used to assist in the preparation of this review. The author has no conflicts of interest that are directly relevant to the content of this review.

References

1. Bishop D, Burnett A, Farrow D, et al. Sports-science roundtable: does sports-science research influence practice. Int J Sports Physiol Perform 2006; 1: 161-8
2. Farquhar CM, Stryer D, Slutsky J. Translating research into practice: the future ahead. Int J Qual Health Care 2002; 14: 233-49
3. Lamb S, Greenlick MR, McCarty D. Bridging the gap between research and practice: forging partnerships with community-based drug and alcohol treatment. Washington, DC: National Academy Press, 1998
4. Webb C, Mackenzie J. Where are we now? Research-mindedness in the 1990s. J Clin Nurs 1993; 2: 129-33
5. Sussman S, Valente TW, Rohrbach LA, et al. Translation in the health professions: converting science into action. Eval Health Prof 2006; 29: 7-32
6. Ginexi EM, Hilton TF. What’s next for translation research? Eval Health Prof 2006; 29: 334-47
7. Greenwood J. Nursing research: a position paper. J Adv Nurs 1984; 9: 77-82
8. Camiah S. Utilization of nursing research in practice and application strategies to raise research awareness amongst nurse practitioners: a model for success. J Adv Nurs 1997; 26: 1193-202
9. Abraham A, Collins D. Examining and extending research in coach development. Quest 1988; 50: 59-79

10. Flay BR. Efficacy and effectiveness trials (and other phases of research) in the development of health promotion programs. Prev Med 1986; 15: 451-74
11. Greenwald P, Cullen JW. The new emphasis in cancer control. J Natl Cancer Inst 1985; 74: 543-551,
12. Glasgow RE, Lichtenstein E, Marcus AC. Why don't we see more translation of health promotion research to practice? Rethinking the efficacy-to-effectiveness transition. Am J Public Health 2003; 93: 1261-7
13. Finch C. A new framework for research leading to sports injury prevention. J Sci Med Sport 2006; 9: 3-9
14. Van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries: a review of concepts. Sports Med 1992; 14 (2): 82-99
15. Bishop D. Editorial. J Sci Med Sport 2007; 10: 73
16. Chalmers DJ. Descriptive studies: we need them but let's keep them in perspective. J Sci Med Sport 2006; 9: 431-2
17. Atkinson G, Coldwells A, Reilly T, et al. The influence of age on diurnal variations in competitive cycling performances. J Sports Sci 1994; 12: 127-8
18. Bishop D, Edge J, Goodman C. Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women. Eur J Appl Physiol 2004; 92: 540-7
19. Bishop D. Physiological predictors of flat-water kayak performance in women. Eur J Appl Physiol 2000; 82 (1/2): 91-7
20. Bishop D, Edge J, Goodman C. The relationship between muscle buffer capacity and repeated-sprint ability in females. Eur J Appl Physiol 92: 2004; 540-7
21. Bishop D, Davis C, Edge J, et al. Induced metabolic alkalosis affects muscle metabolism and repeated-sprint ability. Med Sci Sports Exerc 2004; 36 (5): 807-13
22. Hagberg JM, Coyle EF. Physiological determinants of endurance performance as studied in competitive racewalkers. Med Sci Sports Exerc 1983; 15: 287-9
23. Coyle EF, Coggan AR, Hopper MK, et al. Determinants of endurance in well-trained cyclists. J Appl Physiol 1988; 64 (6): 2622-30
24. Edge J, Bishop D, Goodman C. The effects of training intensity on muscle buffer capacity in females. Eur J Appl Physiol 2006; 96: 97-105
25. Edge J, Bishop DJ, Goodman C. Effects of chronic NaHCO3 ingestion during interval-training on changes to muscle buffer capacity, metabolism and short-term endurance performance. J Appl Physiol 2006; 101: 918-25
26. Edge J, Bishop D, Goodman C. Effects of high- and moderate-intensity training on metabolism and repeated sprints. Med Sci Sports Exerc 2005; 37: 1975-82
27. Mook DG. In defence of external validity. Am Psychol 1983; 38: 379-87
28. Moher D, Schultz K, Altman D. The CONSORT statement: revised recommendations for improving the quality of reports of parallel group randomized trials. BMC Med Res Methodol 2001; 1: 2
29. CONSORT: transparent reporting of trials. The Consort E-flowchart [online]. Available from URL: http://www.consort-statement.org/mod_product/uploads/CONSORT%202001%20flow%20diagram.doc [Accessed 2007 Dec 27]
30. Sands WA. How can coaches use sports science? Mod Athl Coach 1998; 36: 8-12
31. Rotheram-Borus M, Duan N. Next generation of prevention interventions. J Am Acad Child Adolesc Psychiatry 2003; 42: 518-26
32. Green LW, Glasgow RE. Evaluating the relevance, generalization, and applicability of research: issues in external validation and translation methodology. Eval Health Prof 2006; 29: 126-53
33. Backer TE. Information alchemy: transforming information through knowledge utilization. J Am Soc Inf Sci 1993; 44: 217-21
34. Fuqua J, Stokols D, Gress J, et al. Transdisciplinary collaboration as a basis for enhancing the science and prevention of substance use and abuse. Subst Use Misuse 2004; 39: 1457-514
35. Elliott B, Khangure M. Disk degeneration and fast bowling in cricket: an intervention study. Med Sci Sports Exerc 2002; 34: 1714-8
36. Gilbert W, Trudel P. Analysis of coaching science research published from 1970-2001. Res Q Exerc Sport 2004; 75: 388-99
37. Haag H. State-of-the-art review of sport pedagogy. Sport Sci Rev 1994; 3: 1-10

Correspondence: Dr *David Bishop*, Facoltà di Scienze Motorie, Università di Verona, via Casorati 43, Verona I-37131, Italy.
E-mail: bishop@motorie.univr.it